FISH PROTECTIVE WATER EXTRACTION METHOD AND APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. Patent Application Serial No. 09/527,416 filed March 17, 2000, which claims the benefit of United States Provisional Patent Application Serial No. 60/124,986, filed March 18, 1999.

FIELD OF THE INVENTION

The present invention relates to liquid extraction, and more particularly to methods and apparatuses for extracting liquid from a body of liquid.

BACKGROUND OF THE INVENTION

Many industrial, commercial and agricultural applications require the extraction of water from bodies of water such as streams, rivers, lakes and oceans, for example. However, conventional water extraction devices suffer from a number of disadvantages.

In order to supply sufficient volumes of water for many applications, the diameter of an intake hose or other conduit inserted into the water must be sufficiently large that fish and other macroscopic objects may be sucked into the hose. This may cause blockages of the intake conduit or cause other difficulties for the application at hand. Moreover, conventional water extraction devices of this nature have proven to be highly destructive to fish stocks. Accordingly, the United States has enacted legislation requiring industries and other water users to provide fish-protective devices on water intake inlets, and other jurisdictions are also expected to enact such legislation.

One previous fish-protective water extraction device involves attaching a hose to a life preserver, such that an inlet opening of the hose is located beneath the water level. The inlet opening of the hose is covered with a mesh, to prevent the entry of fish or other objects. However, it has been found that

such a mesh typically clogs with debris very quickly, requiring frequent intervention to unclog the mesh.

Other extraction devices involve positioning an inlet near the bottom of a body of water, where fewer fish may be found in some cases. However, this approach results in extraction of a considerable amount of silt and other sediment in the water, which may render the water unsuitable for many purposes. For example, such silt and sediment may unduly pollute water required for irrigation, or may cause increased wear on turbine components in hydroelectric stations due to "sand-blasting" by the silt.

Accordingly, there is a need for an improved water extraction method that reduces the likelihood of harming fish, without unduly compromising the quality of the water.

SUMMARY OF THE INVENTION

The present invention addresses the above need by providing a method and apparatus for extracting liquid from a body of liquid. The apparatus includes a conduit terminator operable to terminate a conduit, the conduit terminator having an inlet opening to facilitate conduction of liquid from the body of liquid. The apparatus also has a solid object diverter including at least one solid wall surrounding the inlet opening to define a liquid admitting cavity about the inlet opening to impede solid objects from entering the inlet opening while permitting entry of liquid into the cavity for admission into the inlet opening. The apparatus further includes a positioner operable to position the diverter in a position in the liquid body such that the cavity admits liquid from the body of liquid while the inlet opening admits liquid from the cavity.

Thus, the solid object diverter serves to prevent or impede the entry of fish and other solid objects into the inlet opening of the conduit terminator.

Preferably, the positioner includes floats on opposite sides of the diverter, in which case the apparatus extracts liquid from near the surface of the body of

liquid, thereby greatly reducing the amount of silt and other sediment admitted into the inlet opening of the conduit terminator.

The apparatus preferably includes a housing for providing a passageway for directing liquid past the solid object diverter, in which case the diverter may be in the housing and the floats may cooperate with the housing. The housing preferably has a wall defining a cavity opening for admitting liquid into the liquid admitting cavity, and further defines a gas vent for permitting gas flow into and out of the liquid admitting cavity.

The apparatus may further include a turbulence producing mechanism operable to produce a turbulent flow of liquid from the housing. It has been found that fish are attracted to turbulence, and accordingly, the turbulence produced by the mechanism tends to attract fish toward an outlet end of the housing rather than toward an inlet end, thus reducing the likelihood that fish will pass through the housing.

Preferably, the turbulence producing mechanism includes a venturi accelerator in or formed by the housing, which serves to produce a high-speed flow as the liquid exits the venturi accelerator, resulting in turbulence behind the outlet end region of the housing. In this regard, the housing may include spaced apart converging walls for forming the venturi accelerator.

Advantageously, the converging walls may be adjustably spaced apart to permit adjustment of the spacing between the converging walls. The converging walls preferably include first and second resilient channel members rigidly attached to respective opposite sides of the housing at an inlet end region of the housing, in which case the apparatus further includes first and second adjustable channel spacers at an outlet end region of the housing, operable to resiliently deform the channel members to adjustably inwardly space the channel members from the sides at the outlet end region, to adjustably define the venturi accelerator. Effectively, this permits the intensity of the venturi effect to be adjusted to account for the needs of different locations or different conditions at the same location, or different

applications. For example, to compensate for slower water currents, it is generally desirable to bring the converging walls closer together, to increase the intensity of the venturi effect.

In addition, or alternatively, the turbulence producing mechanism may include at least one blocking member disposed in an outlet end region of the housing.

The housing preferably has a floating object deflector. This serves to deflect floating objects away from the housing, without passing through it.

The solid object diverter preferably has a hydrodynamic shape, such as a teardrop shape, for example.

The apparatus may further include a data acquisition unit for acquiring environmental data.

The floats preferably have hydrodynamic shapes. The floats may include first and second outer fins extending outwardly from opposite sides of an inlet end region of the housing, and extending rearwardly toward an outlet end region of the housing, substantially parallel with the sides. Respective fin spacers extend outwardly from the sides and engage with the respective fins to space the fins from the sides. The floats may then include a buoyant medium in a space defined between the fins and the sides of the housing. It has been found that such a float improves the hydrodynamic shape of the apparatus.

At least one of the floats may include a watertight control housing for containing a control unit within the float.

The apparatus preferably includes a tether connector for tethering the apparatus to an object. For example, an inlet end region of the housing may be connected to a tether which in turn is connected to a fixed object at the bottom of the body of liquid, to ensure that the inlet end region of the housing remains upstream from an outlet end region of the housing.

In accordance with another aspect of the invention, there is provided a method of extracting liquid from a body of liquid. The method involves positioning a solid object diverter in the liquid body, the solid object diverter including at least one solid wall surrounding the inlet opening to define a liquid admitting cavity about the inlet opening, to admit liquid into the cavity while admitting liquid from the cavity into the inlet opening

In accordance with another aspect of the invention, there is provided a method of guiding fish, involving disposing a plurality of water turbulence generators in a body of water at a plurality of respective positions along a desired fish path.

Other aspects and features of the present invention will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

In drawings which illustrate embodiments of the invention,

Figure **1** is a schematic representation of an apparatus for extracting liquid from a body of liquid, according to a first embodiment of the invention;

Figure **2** is a perspective view of an apparatus for extracting liquid from a body of liquid, according to a second embodiment of the invention;

Figure **3** is a top plan view of the apparatus shown in Figure **2**;

Figure **4** is a cross-section along line **4-4** shown in Figure **3**; and

Figure **5** is a top view of an apparatus for extracting liquid from a body of liquid, according to a third embodiment of the invention.

DETAILED DESCRIPTION

Referring to Figure **1**, an apparatus for extracting liquid from a body of liquid according to a first embodiment of the invention is shown schematically at **10**. The apparatus includes a conduit terminator **12** operable to terminate a conduit, the conduit terminator having an inlet opening **14** to facilitate conduction of liquid from a body of liquid shown generally at **16**. The apparatus further includes a solid object diverter **18** including at least one solid wall surrounding the inlet opening **14** to define a liquid admitting cavity **20** about the inlet opening **14** to impede solid objects from entering the inlet opening **14** while permitting entry of liquid into the cavity **20** for admission into the inlet opening. The apparatus also has a positioner shown generally at **22**, operable to position the diverter **18** in a position in the liquid body **16** such that the cavity **20** admits liquid from the body of liquid **16** while the inlet opening **14** admits liquid from the cavity **20**.

Housing

Referring to Figure **2**, an apparatus for extracting liquid from a body of liquid according to a second embodiment of the invention is shown generally at **10**.

In this embodiment, the apparatus includes a housing **30** for providing a passageway for directing liquid past the solid object diverter **18**. The passageway is defined between a housing passage inlet **28** defined by the housing **30** at an inlet end region **50** of the housing, and a housing passage outlet **29** defined by the housing **30** at an outlet end region **52** of the housing. In this embodiment, the diverter **18** is in the housing **30**. Preferably, the breadth of the housing passage inlet **28** is approximately three times the breadth of the diverter **18**.

Referring to Figures **2** and **3**, the housing **30** has a wall, which in this embodiment is a base portion **32** of the housing **30**, defining a cavity opening **36** for admitting liquid into the liquid admitting cavity **20**. In this embodiment, the cavity opening **36** is shaped and sized similarly to a cross-section of the

diverter **18** that defines the cavity **20**, although it will be appreciated that the shapes and sizes of the cavity opening **36** and the cavity **20** need not be the same.

In this embodiment, the housing **30** further defines a gas vent **38** therein, for permitting gas flow into and out of the liquid admitting cavity. The gas vent **38** includes a plurality of apertures formed through a cover portion **34** of the housing **30**. However, a single aperture, or other types of gas vents, such as one or more pipes extending upwardly from the cover portion **34** for example, may be substituted for the plurality of apertures.

Preferably, the base portion **32** and the cover portion **34** of the housing **30** are separated by a distance ranging from two to three times the breadth of the diverter **18**.

The housing **30** further includes a floating object deflector shown generally at **40**. In this embodiment, the floating object deflector **40** is formed by the cover portion **34** of the housing **30**, which terminates in a V-shaped portion pointing away from the diverter **18** and extending distally further from the diverter than the base portion **32**. The deflector **40** serves to redirect floating debris away from the housing **30**, thus preventing such floating debris from becoming stuck within the housing.

The housing **30** further includes a tether connector **62** for tethering the apparatus to an object. In this embodiment, the tether connector **62** is located on the base portion **32** of the housing **30**, near the inlet end region **50** of the housing. When a tether is connected at one end to the tether connector **62** and at another end to a fixed object such as a concrete block at the bottom of a river bed for example, the tether will serve to pull the inlet end region **50** in a direction opposite to the current flow in the river, so as to orient the housing **30** with the inlet end region **50** upstream of the outlet end region **52**. Alternatively, it will be appreciated that a plurality of tether connectors may be substituted, and that the location on the housing of the tether connector or

plurality of such connectors may be varied. For example, a two-, three- or four-point tether connector may be appropriate depending on site conditions.

Diverter and Conduit Terminator

Referring to Figures **2** and **3**, in this embodiment the solid object diverter **18** includes at least one solid wall surrounding the inlet opening **14** to define the liquid admitting cavity **20**. More particularly, in this embodiment the at least one solid wall includes a vertical wall **70** extending between the base portion **32** and the cover portion **34** of the housing **30**. In this embodiment, the vertical wall **70** extends in a closed loop, to define the liquid admitting cavity **20** therein. The diverter **18** preferably has a hydrodynamic shape, which in this embodiment is a teardrop shape formed by the closed loop vertical wall **70**.

In this embodiment, the solid object diverter **18** is connected to the conduit terminator **12** by a connector shown generally at **72**, which in this embodiment includes first and second opposed rivets, each rivet extending through the diverter **18** and conduit terminator **12** at respective opposite sides. Preferably, the diverter **18** is loosely riveted to the conduit terminator **12** to permit pivoting of the conduit terminator within the diverter, the range of the pivotal motion being limited by an inner surface of the vertical wall **70** of the diverter. Alternatively, other means of connecting the diverter to the conduit terminator may be substituted.

The connector **72** is positioned relative to the diverter **18** and the conduit terminator **12** so as to ensure that the inlet opening **14** of the conduit terminator remains below the water level in the cavity **20** during normal operation.

If desired, the conduit terminator **12** may include a plurality of small apertures (not shown) either within the cavity **20** or extending beneath the housing **30** or both, which serve to decrease the rate at which water is drawn into the inlet opening **14**.

Positioner

Referring to Figure **3**, in this embodiment the positioner **22** includes first and second floats **24** and **26** cooperating with the housing **30**, on opposite sides of the diverter **18**. The floats **24** and **26** preferably have hydrodynamic shapes. More particularly, in this embodiment the floats **24** and **26** include first and second fins **42** and **44** extending outwardly from opposite sides **46** and **48** of the housing **30** at the inlet end region **50**, and extending rearwardly toward the outlet end region **52** of the housing, substantially parallel with the sides **46** and **48**. The housing further includes respective fin spacers **54**, **56**, **58** and **60** extending outwardly from the sides **46** and **48** and engaging with the respective fins **42** and **44** to space the fins from the sides. It will be appreciated that other numbers of fins and/or spacers may be substituted, the fins serving to improve the hydrodynamic shape of the housing **30**. Alternatively, however, other types of floats may be substituted.

Each of the floats **24** and **26** includes a buoyant medium, such as styrofoam shown at **43** and **45** for example, in a space defined between the fins **42**, **44** and the sides **46**, **48** of the housing **30** respectively. Alternatively, other buoyant media or objects may be substituted.

In this embodiment, the float **24** includes a watertight control housing **80** for containing a control unit **82** within the float. If desired, float cover and base portions (not shown) may be provided and sealed to the fin and the housing so that the entire interior of the float containing the control unit is watertight. Alternatively, a smaller watertight housing may be provided within the buoyant medium.

If desired, each of the floats may be provided with a water ballast in a lower portion of the float, to provide a variable buoyancy of the apparatus **10**. The water ballast may be controlled automatically by the control unit **82**, for example.

Turbulence Producing Mechanism

Fish are generally attracted to turbulence, and thus the production of such turbulence may be desirable, in order to guide their motion or swimming paths.

Referring to Figure **3**, to achieve this, the apparatus **10** preferably includes a turbulence producing mechanism shown generally at **90**, operable to produce a turbulent flow of liquid from the housing. More particularly, in this embodiment the turbulence producing mechanism **90** includes a venturi accelerator **92** in, or formed by, the housing.

In the present embodiment, the housing **30** includes spaced apart converging walls **94** and **96** for forming the venturi accelerator. Preferably, the distance between the converging walls **94** and **96** at the outlet end region **52** is approximately one-third the distance between the converging walls at the inlet end region **50**.

The converging walls **94** and **96** are preferably adjustably spaced apart to permit adjustment of the spacing between the converging walls. To achieve such adjustable spacing, in this embodiment the converging walls **94** and **96** include first and second resilient channel members respectively. The resilient channel members are rigidly attached to respective opposite sides **48** and **46** of the housing **30** at the inlet end region **50** of the housing **30**. The apparatus **10** further includes first and second adjustable channel spacers **98** and **100** at the outlet end region **52** of the housing **30**, operable to resiliently deform the channel members to adjustably inwardly space the channel members from the sides at the outlet end region, to adjustably define the venturi accelerator. In this embodiment each of the channel spacers **98** and **100** includes a pair of screws cooperating with corresponding threads in the sides **48** and **46** of the housing, such that clockwise rotation of the screws forces the screws further into the interior of the housing, thereby resiliently inwardly deforming the channel members. Alternatively, other types of adjustable channel spacers may be substituted.

Still referring to Figure **3**, alternatively, or in addition, the turbulence producing mechanism **90** may include one or more blocking members **102** disposed in the outlet end region **52** of the housing. For example, such a blocking member may include one or more small diameter pipes inserted into the base portion **32** of the housing **30**, pointed obliquely downstream. As a further example, one or both of the converging walls **94** and **96** may be provided with a baffle (not shown) to produce the desired turbulence. Other turbulence producing mechanisms will be apparent to one of ordinary skill in the art upon reading this specification, and are not considered to depart from the scope of the invention.

Control Unit

Referring to Figures **2** and **3**, the control unit **82** contained within the watertight control housing **80** of the float **24** acts as a data acquisition unit for acquiring environmental data. To achieve this, the control unit **82** is in communication with a plurality of sensors such as a temperature sensor shown at **84** in Figure **2**. Such sensors may be located at various locations either on or interior to the housing, or alternatively may be located remotely from the apparatus **10**, in wired or wireless communication with the control unit **82**.

More generally, the apparatus **10** may be configured to act as an environmental data buoy, for detecting such properties as temperature, turbidity, depth and atmospheric pressure, for example. Existing sensors to detect these properties and control software to remotely transmit such measured data are well known and need not be described in greater detail. Preferably, however, the control unit **82** and plurality of sensors are configured to act as a satellite-accessible environmental monitoring system similar to that employed in Montana, U.S.A. by the Bureau of Reclamation.

In addition to monitoring environmental data, the control unit **82** may also be configured to monitor performance parameters, such as inefficient operation suggesting debris or blockage, for example.

In this embodiment, the control unit **82** also provides various control functions. For example, if the floats **24** and **26** shown in Figure **3** employ water ballasts, the control unit may be configured to automatically control filling and draining of the ballasts in response to changing environmental conditions, as detected by the plurality of sensors. To achieve this, the control unit may produce signals to actuate a plurality of valves or pumps (not shown) on the floats, for example.

In addition, numerous other features of the apparatus **10** may be automatically controlled by the control unit **82**. For example, each of the adjustable channel spacers **98** and **100** may include an electric motor in communication with the control unit, for automatically decreasing the spacing between the channel members in response to decreasing current.

In addition, if desired, a valve (not shown) such as a butterfly valve may be provided within the conduit terminator **12**, to regulate the flow of liquid into the inlet opening **14**, and could be automatically controlled in response to changing parameters.

As a further example, one or more propellers or fins (not shown) may be provided to permit the control unit **82** to cause the apparatus **10** to swivel within the water, in order to dislodge debris which may have become stuck in the apparatus.

Also, rather than using the tether connector **62** to merely connect a fixed length tether to a fixed object, it may be desirable to automatically vary the length of the tether to compensate for changing water levels, or more particularly, to decrease the length of the tether as the water level drops and increase its length as the water level rises. To achieve this, the control unit **82** may be configured to control a hydraulic or other adjustable unit, to automatically retract or extend the tether in response to changing conditions.

In addition to automatically controlling the above functions, the control unit **82** may include a transceiver for satellite communications, to enable the control

unit to receive control commands from a remote location, and to enable the control unit to transmit environmental and performance data to the remote location.

Suitable control codes for directing the control unit **82** to perform the above functionality may be obtained from REM Technology Inc. of Coquitlam, British Columbia, Canada, a division of Spartan Controls Ltd. of Calgary, Alberta, Canada.

The control unit **82** may be powered by battery systems mounted in the floats, or alternatively, by water-driven turbines mounted along-side or within the housing **30**, and connected to on-board power generating systems or battery charging devices.

Operation

Referring to Figures **2** and **3**, in operation, the solid object diverter **18** is positioned in the liquid body to admit liquid into the cavity **20** of the solid object diverter **18**, while admitting liquid from the cavity into the inlet opening **14** of the conduit terminator **12** about which the solid object diverter **18** extends.

As an illustrative example, the apparatus **10** may be positioned in a river, by virtue of the floats **24** and **26** which keep the apparatus afloat, and by virtue of a tether connected at one end to the tether connector **62** on the base portion **32** at the inlet end region **50** of the housing **30**, and connected at the opposite end to a concrete block submerged at the river bed, for example. The combined effect of the current and the tether attached to the inlet end region **50** will be to maintain the inlet end region **50** of the housing upstream from the outlet end region **52**.

The buoyancy of the floats **24** and **26** is selected such that the apparatus **10** will be almost entirely submerged in normal operation. Ideally, the floating object deflector **40** will be substantially coplanar with the surface level of the

water, to effectively deflect floating objects away from the apparatus **10**. In this substantially submerged orientation, the gas vent **38** will permit any air trapped within the cavity **20** to exit the cavity, thereby effectively admitting liquid into the cavity through the cavity opening **36**, until the water level within the cavity is above the inlet opening **14** of the conduit terminator **12**.

Referring to Figure **4**, the conduit terminator **12** may be connected to a conduit **110**. In this embodiment the conduit terminator is fitted with a joint **112**, and a first end of the conduit **110** is secured to the joint **112** with an O-ring clamp **114**. Alternatively, other means of connecting the conduit to the conduit terminator may be substituted. At least part of the conduit is preferably flexible, to accommodate changes in water levels.

A second end (not shown) of the conduit **110** may then be exposed to a lower pressure than the water pressure at the inlet opening **14** of the conduit terminator **12**, to cause water to be admitted from the cavity **20** into the inlet opening **14** of the conduit terminator **12**, and to flow through the conduit to the second end. The lower pressure at the second end may be generated artificially, if desired, for irrigation or industrial use, for example.

Alternatively, the lower pressure may be generated naturally. For example, dams for hydroelectric power stations often result in less water flow at the surface of a body of water, which causes increased solar heating near the surface. It has been found that such warmer temperatures tend to disorient many fish, rendering them more vulnerable to predators. To partially compensate for this effect, a plurality of apparatuses such as the apparatus **10** may be disposed and tethered in proximity to a dam, and the second ends of the respective conduits **110** may be permitted to dangle freely near the bottom of the body of water. Water currents in the vicinity of the second ends will be greater than those in the vicinity of the inlet openings **14** which are protected by the diverters **18**, and thus, the water currents will generate a lower pressure at the second ends, causing warmer surface water to be drawn into the inlet openings **14** and conducted through the conduits to the

bottom of the body of water. The warmer water drawn from the surface will then be displaced by cooler water rising up from below.

In addition, a plurality of apparatuses **10** may be used to guide fish along a desired fish path. According to the Katzmayer effect, fish often look for the fastest current and face into it, thus travelling backwards downstream. Accordingly, if it is desired to channel fish along a particular path, for example, to channel the fish toward a dam by-pass, a plurality of water turbulence generators such as the apparatus **10** may be disposed in the body of water at a plurality of respective positions along the desired fish path. For example, a plurality of apparatuses **10** may be arranged in a diagonal row across a river, to effectively channel the fish in the direction of the diagonal row.

Alternatives

If desired, the effectiveness of the apparatus **10** in impeding fish and other objects from entering the inlet opening **14** may be further improved. For example, if desired, a second solid object diverter, such as a V-shaped plow for example, may extend downwardly from the base portion **32** of the housing **30**, immediately adjacent the cavity opening **36** of the housing **30**, the "V" pointing in an upstream direction toward the inlet end portion **50**. Alternatively, a mesh or screen may be placed across the cavity opening **36**, although this may pose additional mesh blockage problems.

The apparatus **10** may further include navigation lights (not shown). Such lights may be powered by suitable turbines for example, or alternatively by batteries or other sources (not shown).

In addition, referring to Figure **5**, although a single venturi accelerator apparatus **10** has been described, the apparatus **10** could be modified to provide two or more venturi accelerators. As shown in Figure **5**, an apparatus for extracting liquid from a body of liquid according to a third embodiment of the invention is shown generally at **120**. In this embodiment, the solid object diverter includes a kevlar net **126** surrounding the inlet opening **14** of the

conduit terminator **12**, and further includes inner separator walls **128**, **130** and **132** which cooperate with the housing **30** to define first and second venturi accelerators **122** and **124**. The inlet opening **14** of the conduit terminator **12** is located in a back eddy pool **134**, sheltered downstream behind the venturi accelerators and the kevlar net.

While specific embodiments of the invention have been described and illustrated, such embodiments should be considered illustrative of the invention only and not as limiting the invention as construed in accordance with the accompanying claims.